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Short Communication: Preharvest drought stress varies grain physical characteristics, milling percentage, and nutritional quality of two Job's tears varieties

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Abstract. *Wicaksono FY, Suganda TW, Wuminta, Sinniah UR, Yuwariah Y, Nurmala T. 2022. Short Communication: Preharvest drought stress varies grain physical characteristics, milling percentage, and nutritional quality of two Job's tears varieties. Biodiversitas 23: 1443-1448.* Preharvest drought stress is one of the limiting factors that may affect the quality of the harvested yield. This study aimed to evaluate the grain physical characteristics, milling percentage, and nutritional quality of two varieties of Job's tears (*Coix lacryma-jobi* L.) in response to preharvest drought stress. Two varieties of Job's tears were used in the present study, namely *ma-yuen* (cultivar Watani Wado) and *stenocarpa* (cultivar Watani Kiara Payung) at Ciparanje research station (6.9164° S, 107.7717° E) from July 2018 (dry season) to January 2019 (rainy season). A water-sufficient condition was achieved by irrigating the plant once a day, while a water-deficient condition was formed by the irrigation every 3 days using a sprinkler system. The results showed that preharvest drought stress caused a significant reduction of seed size in both varieties. However, the *stenocarpa* was the only one with a significant reduction in milling yield due to its long seed length. In terms of nutritional quality, *ma-yuen* showed no significant response to preharvest drought, while *stenocarpa* showed a significant gain in protein and calcium. This finding opened the high potential of *stenocarpa* variety to be used both as an ornament, just like recent usage, and also functional food.

Keywords: Climate change, drought stress, functional food, hanjeli, *ma-yuen*, *stenocarpa*

INTRODUCTION

Preharvest factor is previously known to have impact on plant growth, quantity and quality of yield. Ecological conditions, such as agroclimatic and soil characteristics, of growing area is reported to relate with the plant yield quantity and quality (Jim 2013; Efendi et al. 2021; Efendi and Budiarto 2022). Preharvest factor in terms of different maturation stage is reported to have different nutritional content (Mubarok et al. 2021). Preharvest culture practices such as pruning, shading, bending, bagging, are reported to vary the plant's response in terms of physiology, phenology, production and nutritional contents (Budiarto et al. 2018; Budiarto et al. 2019; Budiarto et al. 2022; Widyastuti et al. 2022). Preharvest unfavorable conditions such as drought are dominantly reported to be major constraints for production and yield quality of crop, for example Job's tears (Wang et al. 2017a, 2017b).

Job's tears (*Coix lacryma-jobi* L.) is one of the less popular cereal crops that could potentially be used as a staple food due to its high nutritional value, i.e., carbohydrate of 71.81%, protein of 10.89%, ash of 1.38%, lipid of 5.18% (Nurmala et al. 2017), triglycerides, β-sitosterol, and calcium (Wang et al. 2014; Bhandari et al. 2012; Manosroi et al. 2016). The production of Job's tears is significantly declined by the lack of water supply (Wicaksono et al. 2022). Global warming, which has recently gotten worse, has caused weather anomalies that potentially threaten the water supply to the crops (Nawiri et al. 2017). The weather anomaly is associated with the variation of the start and end of the rainy season (Iizumi et al. 2014; Nur'utami and Hidayat 2016; Rodysill et al. 2019). The shifting of the rainy season affects the growth and development of crops (Berg et al. 2013; Guan et al. 2015). The recent occurrence of weather anomalies should be overcome by providing the appropriate planting calendar, especially for dry upland (Iizumi and Ramankutty 2015; Avia 2019; Sukerta et al. 2020) and choosing the adaptive variety (Macholdt and Honermejer 2016; van Etten et al. 2019).

Two varieties of Job's tears plants frequently cultivated in Indonesia are *ma-yuen* and *stenocarpa*. The difference between both varieties is easily recognized based on the seed characteristics, i.e., *ma-yuen* and *stenocarpa* have soft and hard-shelled seeds, respectively (Nurmala et al. 2016). The *ma-yuen* variety has earlier maturity stage than *stenocarpa*, i.e., 55 days earlier (Wicaksono et al. 2021). One of the local cultivars of *ma-yuen* variety is Watani Wado, while the local cultivar of *stenocarpa* is Watani Kiara Payung. Earlier studies reported the effect of drought stress on Job's tears can be the delay of crop phenology, and the reduction of growth and yield (Wicaksono et al. 2022, Ruminta et al. 2017). However, there is still less information on how preharvest drought stress may affect

the quality of harvested grain. In terms of external quality, the high quality of harvested grain can be classified by the lower portion of broken grain (20-40%) for the market (Salassi et al. 2013; Custodio et al. 2019). In terms of internal or nutritional quality, several earlier studies reported the influence of water supply on protein, carbohydrates, fat, and calcium in kernels (Zao et al. 2009; Emam et al. 2014; Sehgal et al. 2018; Dimkpa et al. 2019). Therefore, this study aimed to evaluate the external (grain physical characters), milling quality, and internal (nutritional) quality of Job's tears in response to preharvest drought stress condition.

MATERIALS AND METHODS

Plant materials

Two varieties of Job's tear were used in the present experiment, namely *ma-yuen* and *stenocarpa*. Both varieties were popularly known as local Job's tears variety (Wicaksono et al. 2022). The seed was obtained from the laboratory of crop production technology, Faculty of Agriculture, Universitas Padjadjaran. The *ma-yuen* variety was characterized by an early maturing character (6 months after planting) and a small plant size (270 cm in height and 40x60 cm in canopy size). The *stenocarpa* was characterized by late maturity (7 months after planting) and large plant size (300 cm in height and 80x60 cm in canopy size).

Planting site

The present experiment was carried out under open field conditions at Ciparanje research station of the Faculty of Agriculture, Universitas Padjadjaran, West Java Province, Indonesia (6.9164° S, 107.7717° E, 730 m above sea levels) from July 2018 (dry season) to January 2019 (rainy season). The soil characteristics of the study site were depicted in Table 1. The agro-climatic characteristics of the study site were derived from meteorological data recorded by the nearby climate station (100 m away from the field), i.e., Ciparanje climatology station of Faculty of Agriculture, Universitas Padjadjaran, as shown in Table 2.

Procedure

In the present experiment, the direct seeding method with a crop spacing of 60 cm×80 cm. The land was exposed by full tillage using hand tractor a week prior to planting. Organic fertilizer in form of compost was applied at the same time with soil tillage. There was only one seed per planting hole. Replanting was conducted 14 days after sowing. The compound fertilizer in the form of NPK (15:15:15) was applied a week after sowing at a rate of 200 kg ha^{-1}, following previous study by Wicaksono et al. (2022). Hand weeding was applied four times at 15, 30, 45 and 60 days after sowing.

The plant was arranged in two populations, i.e., *ma-yuen* and *stenocarpa*, and subjected to preharvest drought stress and preharvest normal water sufficiency as control. There were 300 plants in every population in the early of July. The drought stress was created by the regulation of irrigation levels. A water-sufficient condition was achieved by irrigating the plant once a day, while a water-deficient condition was formed by irrigation every 3 days. The irrigation was made using a sprinkler system for about 2 hours, at 8-10 am, with a volume of 0.19 m^3, equal to 57.6 liters per plant or 12 mm of daily rainfall. This water volume was in agreement with the daily water need of Job's tears as implied by Ruminta et al. (2017). The treatment of drought stress was applied from 6 to 12 weeks after sowing (late August to early October).

Measured variables

The harvesting time of both varieties were different from one another, i.e., *ma-yuen* (6 months after sowing) and *stenocarpa* (7 months after sowing). Seeds were harvested from each population that consisted of the 30 plants. The harvested seed was further processed into grain by using a milling process. The seed was then air-dried to form 12% moisture content for further grain evaluation. There was no free water in seed below 12% seed moisture content, so the seed is storable and ready for further testing (Nijënstein 2008).

There were three main measured variables in the present study, i.e., grain physical characteristics, milling yield, and nutritional quality. Grain physical characteristics were seed length, seed width, and seed hardness. Seed length and seed width were measured by a digital caliper (Mitutoyo, Japan). Penetrometer (Wagner, USA) was used to determine the hardness of Job's tears seed and then expressed in the hardness unit of Kgf (Li et al. 2016). There were 30 seeds per plant randomly provided for this measurement.

Table 1. The result of soil analysis in experimental site

Variables	Unit	Value
pH H_2O	-	5.98
pH KCl 1 N	-	4.63
Texture components:		
Sand	(%)	10.26
Silt	(%)	26.85
Clay	(%)	50.89
Field capacity	(%)	10.3

Table 2. Meteorological data recorded by Ciparanje climatology station of Faculty of Agriculture, Universitas Padjadjaran from July 2018 to January 2019

Month	T (ºC)	RH (%)	P (mm)	SD (h)
July	22.1	82	0	7.81
August	22.3	85	0	7.08
September	23.5	79	4	7.05
October	24.3	81	62	7.15
November	23.6	90	62	4.50
December	23.2	92	189	4.45
January	23.2	91	212	4.25

Notes: T is average temperature; RH is average relative humidity; P is total precipitation; SD is average sunshine duration

There was 2 kg of Job's tears grains in each treatment provided for the milling process. The milling yield was the percentage of finished product (grain) derived from the milling of cereal seed of Job's tears. All measuring procedures were carried out according to an earlier study dealing with rice's physical quality (Ponnappan et al. 2017).

The nutritional quality variable was protein, lipid, carbohydrate, and calcium. The analysis of the protein, lipid, and carbohydrate content was done by using the Kjeldahl's method (Latimer 2016), Soxhlet method (Zhu et al. 2014), and proximate method (Al-Reza et al. 2015), respectively. The calcium content was analyzed by Spectro-Direct according to the method described by Tiwow et al. (2016) with a slight modification. Furthermore, 15 g of Job's tears powder was diluted with 20 mL of HNO_3 20 ml and filtered before being diluted with 100 mL of H_2O. 10 mL of dilution and $C_{20}H_{26}NO_3$ were added to the flask and shaken until a pink color appeared.

Statistical analysis

The data was statistically tested by an *F-test* to obtain the variance among tested treatments at a 5% significance level. Furthermore, the student's *t*-test was carried out to test any significant differences in the mean of measured variables. A correlation analysis was performed by using Pearson coefficient method among seed size and milling yield. Statistical analysis was done by using SPSS version 21 (IBM Corp 2012).

RESULTS AND DISCUSSION

Grain physical characteristics

Preharvest drought stress affected the grain physical characteristics of two varieties of Job's tears. There was a difference in grain's physical characteristics of the two varieties of Job's tears in stress conditions as compared to normal ones. Seed size (seed width and length) and seed hardness were significantly decreased under water shortage conditions in both *ma-yuen* and *stenocarpa* varieties (Table 3). The reduction of seed width of *ma-yuen* and *stenocarpa* varieties treated by preharvest drought was 13% and 8%, respectively, compared to control. The reduction of seed length of *ma-yuen* and *stenocarpa* treated by preharvest drought was 3% and 5%, respectively, compared to control. The reduction of seed hardness of *ma-yuen* and *stenocarpa* treated by preharvest drought was 30% and 11%, respectively, compared to control. An earlier study reported that crops grown under deficit irrigation had 4% lower grain hardness than those grown in normal conditions (Ali et al. 2011). In addition, the reduction of grain size, as the effect of drought stress, was also reported by numerous studies, that was potentially caused by the decline of grain moisture content (Pierre et al. 2007; Xue 2008, Noorka et al. 2009) and also the reduction of photoassimilates production and translocation (Sehgal et al. 2018). Similar to Job's tears, wheat's grain volume also became the main important factor determining the yield quality (Otteson et al. 2008).

Table 3. Grain physical characteristics and milling yield of two varieties of Job's tears in response to preharvest drought stress

Grain physical characters	Variety	
	ma-yuen	***stenocarpa***
Seed width (cm)		
Everyday watering	0.45±0.029 b	0.52±0.027 b
Every 3 days watering	0.39±0.027 a	0.48±0.027 a
Seed length (cm)		
Everyday watering	0.61±0.036 b	0.77±0.059 b
Every 3 days watering	0.59±0.032 a	0.73±0.057 a
Seed hardness (kg)		
Everyday watering	3.22 ± 0.23 b	7.46 ± 0.46 b
Every 3 days watering	2.26 ± 0.08 a	6.63 ± 0.32 a
Milling yield (%)		
Everyday watering	54.48±5.35 a	49.42±5.78 b
Every 3 days watering	52.86±5.40 a	38.16±3.47 a

Note: Mean ± standard of error in the same column within the similar physical characters followed by the same lowercase letter are not significantly different based on students' *t*-test at 5% level.

Grain milling percentage

The yield of the *ma-yuen* variety was not significantly reduced by drought stress, but the *stenocarpa* did (Table 3). The *ma-yuen* showed a higher drought tolerance performance than *stenocarpa.* The decrease in milling yield of *stenocarpa* under stress conditions was 23% compared to normal conditions. In general, the drought stress could threaten the number of harvested grain yields (Ullah and Farooq 2021), since the drought could alter plant photosynthetic capacity, leading to the problem of grain filling (Sehgal et al. 2018).

The decrease in milling yield was associated with a decrease in seed length. This finding was in accordance with previous results (Wills and Ali 1983; Doehlert and Wiessenborn 2007). The small size of the seeds was easily broken and then blown by the crushing machine blower as a waste. Earlier studies had reported that seed weight, the main variable determining the milling yield, is correlated to seed size (Abdipour et al. 2016). In terms of seed size, the seed width was not significantly correlated to the milling yield, while the seed length showed a significant relationship (Table 4). The significant reduction in yield of the *stenocarpa* variety was due to the greater percentage reduction in seed length of the *stenocarpa* variety (5%) than the *ma-yuen* variety (3%).

Grain nutritional quality

The preharvest drought stress caused a variety of nutritional quality in two varieties of Job's tears grain. The content of protein, lipid, carbohydrate, and calcium in *ma-yuen* variety was not significantly affected by the preharvest drought stress (Table 5). The protein, lipid, carbohydrate, and calcium content in *ma-yuen* variety varied from 8.67 to 9.26%, 1.33 to 1.42%, 77.56-77.78%, and 45.61-47.91%, respectively. In the *stenocarpa* variety, the preharvest drought stress significantly affected the protein, lipid, and calcium content (Table 5). The protein content varied from 8.67 to 9.26%, which implied that the protein content was significantly increased by about 12% by preharvest drought stress. The lipid content was

significantly decreased by about 30% by preharvest drought stress. Meanwhile, the carbohydrate content was relatively decreased by about 2% by preharvest drought stress. In contrast, the calcium content was significantly increased by about 10% by preharvest drought stress.

The increase in protein and calcium content in Job's tears cereals of *stenocarpa* variety after being treated with preharvest drought stress was an adaptation strategy to overcome the damage of preharvest drought stress. Several proteins, such as dehydrin and late embryogenesis abundant protein (LEA), were produced in seeds to suit osmotic conditions (Carjuzaa et al. 2008; Liu et al. 2019), leading to more adaptive performance. Calcium was also accumulated in seeds to adjust osmotic conditions and signal transduction (Wei et al. 2014; Emam et al. 2014). The decrease in lipid content in the *stenocarpa* variety probably occurred due to the damage to the lipid membrane in the seeds (Gunes et al. 2008; Anjum et al. 2011).

Variation in the nutritional quality of Job's tears cereals of *stenocarpa* under water shortage conditions was not worrying because the *stenocarpa* variety grain is still used for ornaments and jewelry (Qosim and Nurmala 2011). However, the increase in calcium and protein content and the decrease in lipid content as the effect of preharvest drought enhanced the potential of this variety to be further used as a functional food.

Table 4. Pearson's correlation between seed size (length and width) to milling yield of two varieties of Job's tears in response to preharvest drought stress

Seed size	Correlation value to milling yield
Variety of *ma-yuen*	
Seed width	0.128
Seed length	0.156
Variety of *stenocarpa*	
Seed width	0.166
Seed length	0.295*

Note: * – significantly correlated at 95% confidence level

Table 5. Nutritional quality variables of two varieties of Job's tears in response to preharvest drought stress

Nutritional quality variables	Variety	
	ma-yuen	***stenocarpa***
Protein (%)		
Everyday watering	8.67±0.64 a	8.22±0.44 a
Every 3 days watering	9.26±0.86 a	9.20±0.90 b
Lipid (%)		
Everyday watering	1.42±0.21 a	1.03±0.15 b
Every 3 days watering	1.33±0.26 a	0.72±0.14 a
Carbohydrate (%)		
Everyday watering	77.78±1.38a	79.28±1.53 a
Every 3 days watering	77.56±1.44a	77.75±1.95 a
Calcium (mg/g)		
Everyday watering	45.61±5.35a	51.59±5.78 b
Every 3 days watering	47.91±5.40a	56.74±3.47 a

Note: Mean in the same column within the similar nutritional quality variable followed by the same lowercase letter are not significantly different based on students' *t*-test at 5% level

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